Preparation and characteristic study of particle board from solid waste

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Preparation and characteristic study of particle board from solid waste

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Abstract. The objective of this study is to use municipal dry waste, plant waste and saw dust collected from various sources to make particle boards with each individual item as well as a combination of these in various ratios. Since most of the previous studies done are by making use of fibers, the present work focuses on finding the properties of the board without the use of fibers. The physical and mechanical properties of these boards are then determined by using a series of tests like moisture content test, water absorption properties, thickness swelling, tensile test, compressive test and flexural strength. The results are then compared and most of the samples are found to comply with the IS standards.

1. Introduction

In recent years, recycling and reusing techniques of different kinds of bio-degradable wastes have become an important part of the sustainable utilization of resources. These alternative raw materials can play a growing tendency and major role in Particle Board industry [1]. Using of residues of various products in the production of Particle Boards is very profitable in economical and environmental terms [2, 3].

Population increase and migration of people to industrial towns and cities from rural areas resulted in a consequent increase in the domestic and industrial waste, posing threat to human health and environmental issues of water quality, air pollution, and land toxicity issues. Our population is still growing and we are producing more garbage, even with the recycling efforts in full operation. Municipal solid waste (MSW) is garbage that comes from homes, businesses, and schools are recycled whenever economical and/or practical. The residential waste sources were estimated to be 55–65% of total MSW generation. Commercial waste sources (including waste from schools, some industrial sites where packaging is generated, and businesses) constitutes between 35 and 45% of MSW generation [4]. Some of the types of waste and their sources are discussed

Table 1 Types of waste and their sources

Type	Sources
Organic	Food craps, yard (leaves, grass, brush) waste, wood, process residues

Paper	Paper scraps, cardboard, newspapers, magazines, bags, boxes, wrapping paper, books pages, shredded paper, paper beverage cups.
Plastic	Bottles, packaging, containers, bags, lids, cups
Glass	Bottles broken glassware, light bulbs, colored glass
Metal	Cans, foil, tins, non-hazardous aerosol cans, appliances (white goods), railings, bicycles
Other	Leather, rubber, multi-laminates, e-waste, appliances, ash, other inert materials

Municipal solid waste is being generated in large quantities in all the cities in the world. As per information by Joshi and Ahmed [5] in between the year (2009-12), 1, 27,486 TPD (Tons per day) municipal solid waste is generated in the Country during 2011-12. Out of which, 89,334 TPD (70%) of MSW is collected and 15,881 TPD (12.45%) is processed or treated. Keeping in view the rapid urbanisation the reuse of municipal solid waste is an imperative design and utmost importance to create efficient MSW disposal facilities in India to meet the needs of rapidly growing metropolises and other cities. Mostly suggested methods for MSW disposal are incineration, pelletisation and combustion for steam generation and power production.

Particle Board is a product manufactured under pressure from different kinds of wastes, wood or other materials and an adhesive. Particle Boards are produced from Municipal solid waste, agro-waste materials such as coconut coir[6], rice husk, jute sticks, waste wood, sugarcane wastes and kitchen waste[7]. Particle Board can also be produced from watermelon peels[8]; kelempayan[9]; waste paper treated with maleic anhydride [10]; Peachnut Shell with impregnated with Glass Powder[11] as an alternative to wood based Boards. Particleboard is commonly used for cabinetry, tabletops, shelving, wall and floor panels, partition walls , doors, furniture, and other non-structural architectural applications.

The present study is done to assess the physical and mechanical properties of the Particle Boards manufactured from Municipal solid waste, saw dust and plant waste in different combinations. These properties play an important role in manufacturing the Particle Boards when compared with the standards.

2. Materials and methods

a) Sample collection: Raw materials used in this research are a Municipal solid waste, Saw dust and plant waste. Municipal solid waste is collected from Ranipet dumping site located in Tamil Nadu. Saw dust and Plant waste are sourced locally from VIT University.

b) Segregation, Drying, Shredding and Grinding: Collected Municipal solid waste is segregated i.e. Bio-degradable and Non-Bio-degradable waste, only Bio-degradable waste is used for the Particle Board production. Segregated waste was then dried in the sun for almost two weeks so as to reduce the moisture content. After the Moisture content reduction, dried waste is shredded and grinded into powder. It was reduced to fine particles before passing through the standard sieves.

c) Resin impregnation: Urea Formaldehyde resin is formulated in the laboratory. (Urea: Formaldehyde=1:1). This Urea and Formaldehyde solution is heated at 70oc for a period of 15 minutes until the resin achieved polymerisation i.e. when the desired viscosity is reached. This liquid resin and filler material were impregnated and blended together manually.

d) Hydraulic pressing: After homogenous mixture, the filler is poured into the rectangular mold. Top of the mold is covered with another metal and was conveyed to the hydraulic press by applying heavy weight with a temperature of 100oC where the press applies heat and pressure to activate the resin and bond the fiber into the solid panel.

e) Testing methods:
Testing method was adopted for density, moisture content, water absorption, thickness swelling, tensile strength, compressive and flexural strength based on the recommendation by Wang et al.[12]; Chen et al.[13] and Laemlaksaku [14] as per the standard per IS3087.

Tensile strength
Internal bond strength is commonly examined property for any type of Particle Boards. In terms of strength properties, this is one of the properties which have a lot of significance. Tensile strength test is a mechanical test performed on packaging materials to determine the maximum load that can be applied to a material before it ruptures or tears Tensile testing machine is used to calculate the tensile strength. The sample was placed on the machine and anchored at both ends. As the machine was pumped manually, both tensioned ends were stretched till it failed. The failure occurred by splitting. Tensile tests were carried out using Instron model 8801 Universal testing machine.

Compressive strength
Compressive strength is a maximum stress that a material can sustain under crush loading. It is nothing but the maximum amount of compressive load a material can withstand before fracturing. The sample piece is compressed between the platens of a compression testing machine by a gradually applied load. Compressive tests were carried out using Instron model 8801 Universal testing machine.

Flexural strength
Modulus of rupture is an important property determining the application of the product for structural components. This property results will depend according to the board density. A concentrated bending load was applied at the center with a span of 15 times the thickness of the Specimen (Laemlaksaku., 2010)]. Flexural tests were carried out using Instron model 8801 Universal testing machine.

3. Results and discussion

3.1 Density
Fabricated Particle Boards were tested for the density according to the following formula. Density (g/cm3) = Wa/Va. where Wa- air dried weight and Va – air dried volume. The board after being prepared is cut into small sections. Each sample is then weighed using a calibrated weighing machine and recorded as shown in Table 2.

Table 2: Properties of the prepared particle board

SNo	Sample type	Density (kg/m^3)	Moisture content (%)	Water absorption (%)	Thickness swelling (%)
1	Municipal solid waste	902	8.06	34.1	2.7
2	Municipal solid waste and saw dust	924	7.27	30.1	2.4
3	Saw dust	921	3.97	31.3	2.6
4	Plant waste	1030	6.83	13.17	1.25

The density values obtained from this work as seen from the table is in accordance with the standard range. The minimum value is obtained for the board prepared from municipal solid waste and the maximum is obtained for that prepared from plant waste.

3.2 Moisture content
The moisture content of the Particle Boards was tested as per the relation, Moisture content (%) = (Wa - Wo/Wo)*100 where Wo- Oven dried weight of the particle board. The moisture content for the board sections is found out by taking each sample, weighing it in the air and then drying it in an oven at 100 degrees and then finding out the difference between the two values are as shown in the Table 2.

As per IS3087standard, the moisture content in a particle board should be in the range of 5 to 15 %. Any value less or more than the range mentioned has an impact on the linear dimension and thickness of the board. A less moisture content will lead to irregular bending of the board whereas a higher content will effect the strength. As can be seen from the moisture content values from the table, the minimum is obtained for board prepared from saw dust and the maximum is obtained from that prepared from municipal solid waste.

3.3 Water Absorption

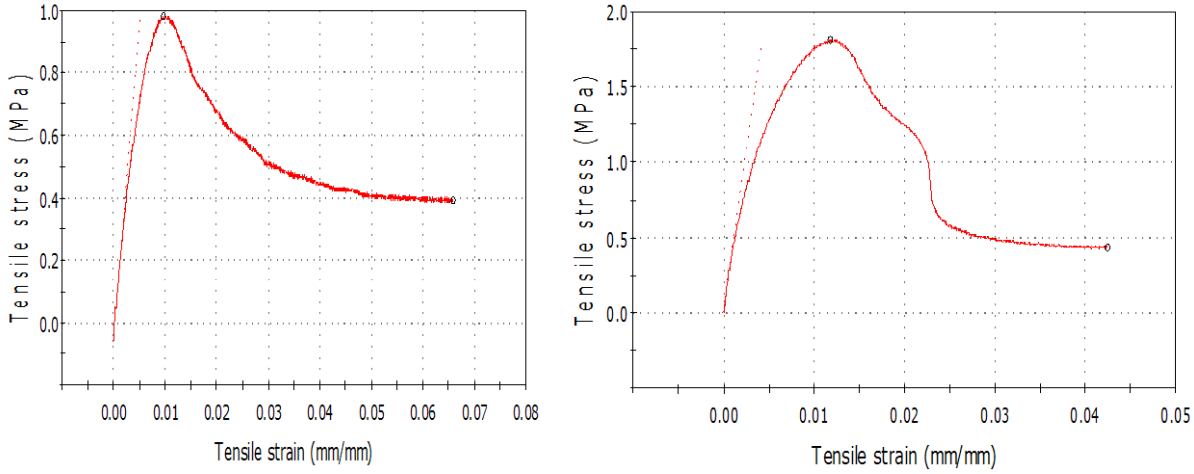
The water absorption test for each particle board is done as per IS3087. The board is soaked for two hours at room temperature and then measuring the weight of each and then soaking them again and repeated the procedure till a constant weight is obtained. Water Absorption of the Particle Board is measured using the relation, Water absorption (%) = (Wf – Wi/Wi)*100 where Wf – final weight; and Wi – initial weight. Each board had taken approximate 12 hours to attain a constant weight. The final weight of each is measured and the water absorption value is reported in Table 2. The water absorption percentage should not exceed 40 % [15]. A higher absorption value will lower the strength of the board considerably. As can be seen from the values obtained from the study, the absorption value is in the desired range.

3.4 Thickness Swelling

The thickness swelling test, the thickness of each original sample is first measured and recorded. Then the samples are soaked in water for a period of 24 hours. The thickness of the soaked samples are then measured and the percentage of thickness swelling is calculated. Thickness swelling (%) = (Tf - Ti/Ti)*100, where, Ti = initial thickness and Tf = final thickness . The values obtained are as shown in Table 2. The standard value of thickness swelling percentage is 12 %. Beyond this value, the strength of the board will be affected. From the values obtained from the present work, it can be seen that the thickness swelling values are much less than the maximum value.

3.5 Tensile strength analysis

The samples are cut as per the dimensions mentioned in the standard. Then the samples are fixed on the Universal testing machine (Instron model 8801) and the tensile strength is recorded in the form of a plot of tensile strain vs. tensile stress till the sample breaks. The graphs for the four samples are as shown in Figure 1. The analysis report are given in Table 3.



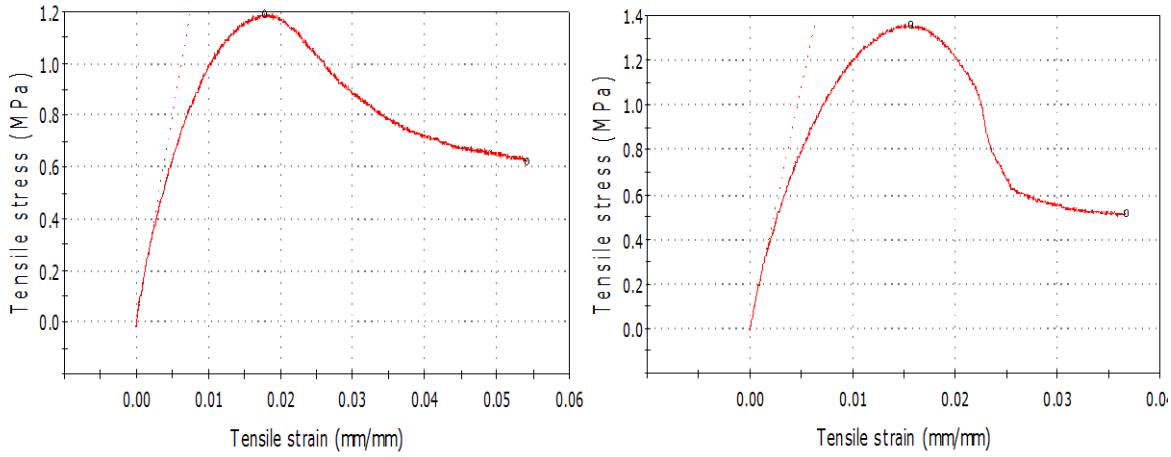


Figure 1 (a) Municipal solid waste and sawdust; (b) saw dust; (c) municipal solid waste (d) plant waste

From the graphs, the saw dust particle board can withstand the maximum tensile stress followed by the plant waste, municipal waste and the municipal waste with saw dust board. These stress values are much higher than the standard minimum tensile stress value of 0.8 MPa. There is a variation in the corresponding strain values with the maximum strain value recorded for the municipal solid waste and the least value for that with the municipal waste with saw dust.

Table 3 Tensile Strength Reports

SNo	Sample type	Tensile strain at max load (%)	Load at break (kN)	Tensile stress at break (mPa)	Uts (mPa)	Max. load (kN)	Modulus (gPa)
1	Municipal solid waste	0.965	0.25	0.39	1	0.61	0.199
2	Municipal solid waste and saw dust	1.177	0.27	0.43	2	1.14	0.422
3	Saw dust	1.768	0.39	0.62	1	0.75	0.158
4	Plant waste	1.565	0.32	0.51	1	0.85	0.214

Table 4 Compressive Strength

SNo	Sample type	Max compressive load (kN)	Compressive stress (mPa)
1	Municipal solid waste	1.90	3.408
2	Municipal solid waste and saw dust	1.19	2.130
3	Saw dust	1.10	1.846
4	Plant waste	1.39	2.328

Table 4: Flexural Strength Results

Sno	Sample Type	Maximum Load (N)	Maximum Flexure Stress (Mpa)	Maximum Extension (Mm)	Modulus (Gpa)
1	MSW and Sawdust	112.31	1.528	2.022	0.070
2	Sawdust	475.59	6.470	2.627	0.288
3	Plant waste	152.40	1.354	2.112	0.031
4	Municipal solid waste	236.17	2.099	2.632	0.0514

3.6 Compressive strength analysis:

The Compressive strength test is done using the Universal testing machine (Instron model 8801) as per the testing procedure on IS 3087 (2005). Four samples of different material i.e. sawdust, plant waste, Municipal solid waste and combination of MSW and sawdust are tested using Instron 8801 Universal testing machine.

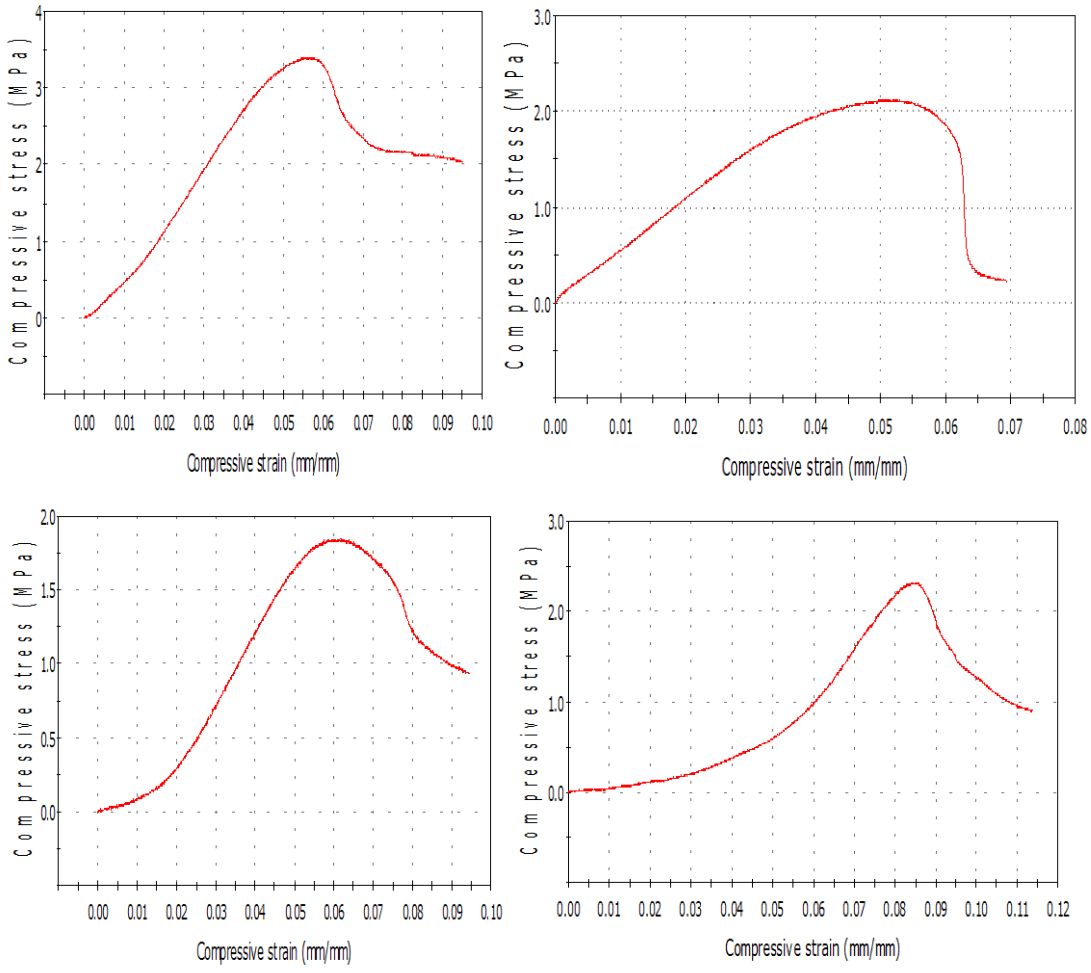


Figure 2. (a) sawdust (b) plant waste; (c) municipal solid waste (d) MSW and sawdust

As can be seen from the table above, among the four samples, the maximum compressive stress and the Maximum compressive load are observed for the Particle Board made with sawdust material.

3.7 Flexural strength analysis

The flexural strength test is done using the Universal testing machine. A square section of the sample is taken for this test. The strain rate maintained for this test is 1 mm/min. The readings are recorded in the form of a plot of flexural strain vs flexural stress as shown in Figure 3.

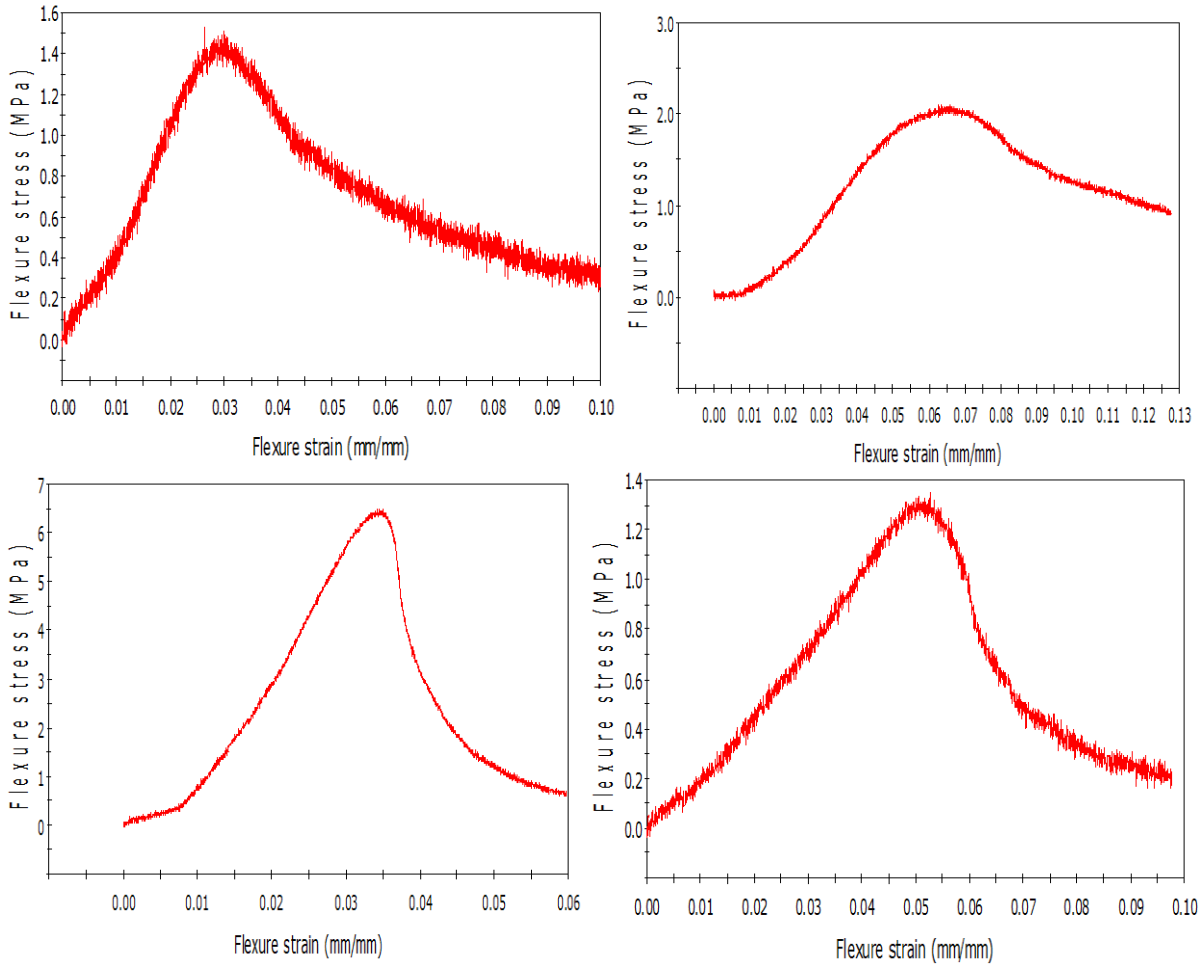


Figure 3. (a) MSW and saw dust; (b)MSW; (c) saw dust;(d) plant waste

Consolidated results have been reported in Table 5 for the maximum load, maximum flexural stress, maximum extension, and modulus from the graphs obtained. From the tables, the maximum flexural stress value is observed for the saw dust particle board and the minimum value for plant waste board. Similarly, the saw dust board is found to withstand the maximum load.

Table.5: Physical and Mechanical Properties of The Particle Board

Properties	Sample 1(Msw)	Sample 2 (Msw And Sawdust)	Sample 3 (Sawdust)	Sample 4 (Plant Waste)	Prescribed Values as IS 3087
Density (Kg/m^3)	902	924	921	1030	500-900
Water Absorption (%)	34.1	30.1	31.3	13.17	Maximum 40%
Thickness Swelling (%)	2.7	2.4	2.6	1.25	Maximum 12%
Moisture content (%)	8.06	7.27	3.97	6.83	5-15
Tensile strength	1	1	2	1	Minimum 0.8

(MPa)					
Compressive strength (MPa)	1.847	2.328	3.408	2.130	>2.5
Flexural strength (MPa)	2.099	1.528	6.470	1.354	9-11

4. Conclusion

The particle board has been made using different base materials which include municipal solid waste, saw dust and plant waste and also a combination of municipal solid waste and saw dust as per standard procedure. An important point to mention here is that all the boards have been prepared without the use of fibers unlike all the previous works did where fiber was one of the key ingredients. The board prepared for this study without the use of fibers have its physical and mechanical properties almost on par with that made using fibers except for its flexural and compressive stress which is lower than the required standards. Water absorption and thickness swelling, which are two of the key qualities compared to commercial usage, has their limits much lower than the standard range and comparable to boards made from other proved materials. The tests conducted on the boards also shows that the board made with saw dust has the best properties among all the others and also meet up with the standards to be used commercially. There is scope for further improvement and experimentation to find alternate materials which will improve the flexural and compressive stress properties of these boards.

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